

Current status of SST + OST combination for B_s -mixing

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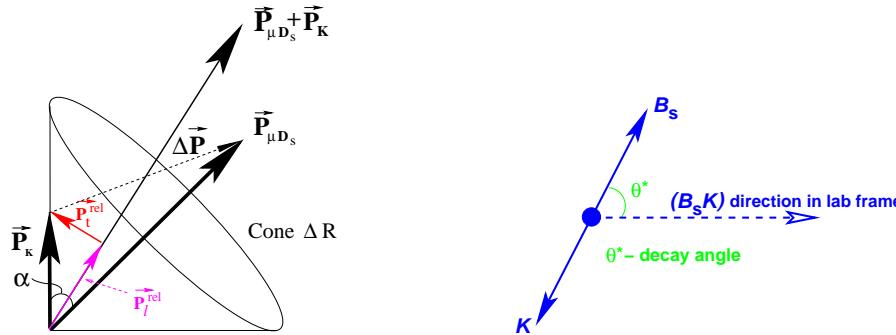
April 19, 2007
 B Mixing and Lifetime

http://www-d0.fnal.gov/~rakitin/d0_private/tex/2007.Apr.19.Bmix/tr.pdf

List of used same-side taggers:

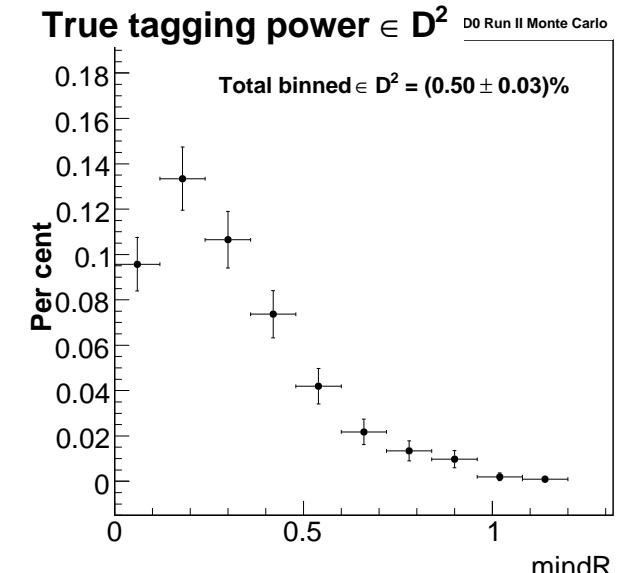
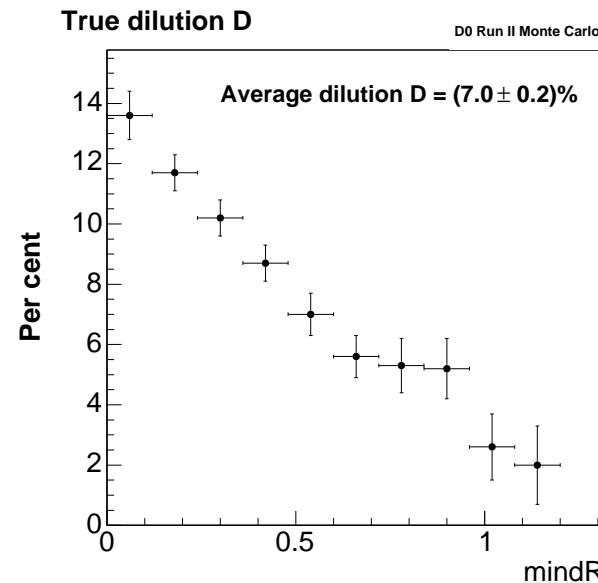
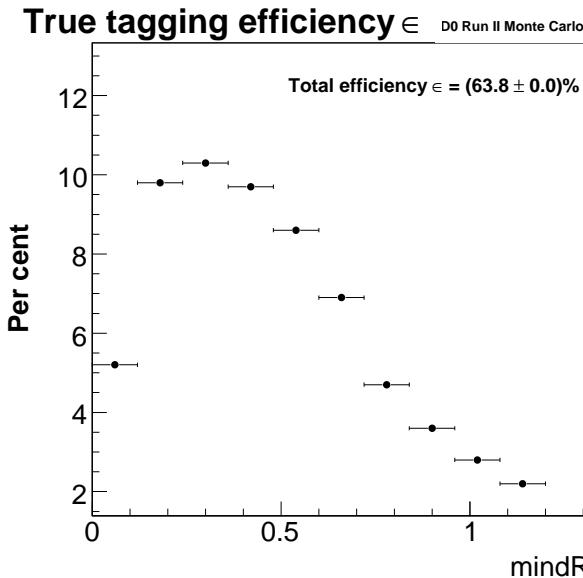
We are using the following SSTs (one-track and many-track taggers):

- | | | |
|--|------------------------|--|
| ☞ Min. p_t^{rel} | ☞ Max. $\cos \alpha$ | ☞ $Q_{\text{jet}}(p_t, \kappa) = \frac{\sum q \cdot p_t^\kappa}{\sum p_t^\kappa}$ |
| ☞ Max. p_L^{rel} | ☞ Min. $\cos \theta^*$ | ☞ $Q_{\text{jet}}(p_t^{\text{rel}}, \kappa) = \frac{\sum q \cdot (p_t^{\text{rel}})^\kappa}{\sum (p_t^{\text{rel}})^\kappa}$ |
| ☞ Max. p_t | ☞ Max. $\cos \theta^*$ | ☞ $Q_{\text{jet}}(p_L^{\text{rel}}, \kappa) = \frac{\sum q \cdot (p_L^{\text{rel}})^\kappa}{\sum (p_L^{\text{rel}})^\kappa}$ |
| ☞ Min. $ \Delta \vec{P} \equiv \vec{p}(B_s) - \vec{p}(K) $ | ☞ Min. $m(B_s K)$ | ☞ Best: $Q_{\text{jet}}(p_t, \kappa = 0.6)$ |
| ☞ Best: Min. ΔR | ☞ Random track | |



- p_t^{rel} and p_L^{rel} are \perp and $||$ components of SST candidate's momentum $\vec{p}(K)$ w.r.t $\vec{p}(B_s K)$
- $\Delta R \equiv \sqrt{\Delta\phi^2 + \Delta\eta^2}$ and angle α are taken between $\vec{p}(B_s)$ and $\vec{p}(K)$
- θ^* – decay angle of $B_s K$ -system, i.e. angle between directions of $\vec{p}(B_s K)$ and $\vec{p}(B_s)$ in reference frame of $B_s K$ system
- Probability for a track to be a kaon is taken from dE/dx (thanks to Derek)
- $\kappa = 0.0, 0.1, 0.2, \dots 1.0$
- p_t^{rel} and p_L^{rel} here are \perp and $||$ components of SST candidate's momentum $\vec{p}(K)$ w.r.t $\vec{p}(B_s)$

Best one-track tagger: “Min. ΔR ”

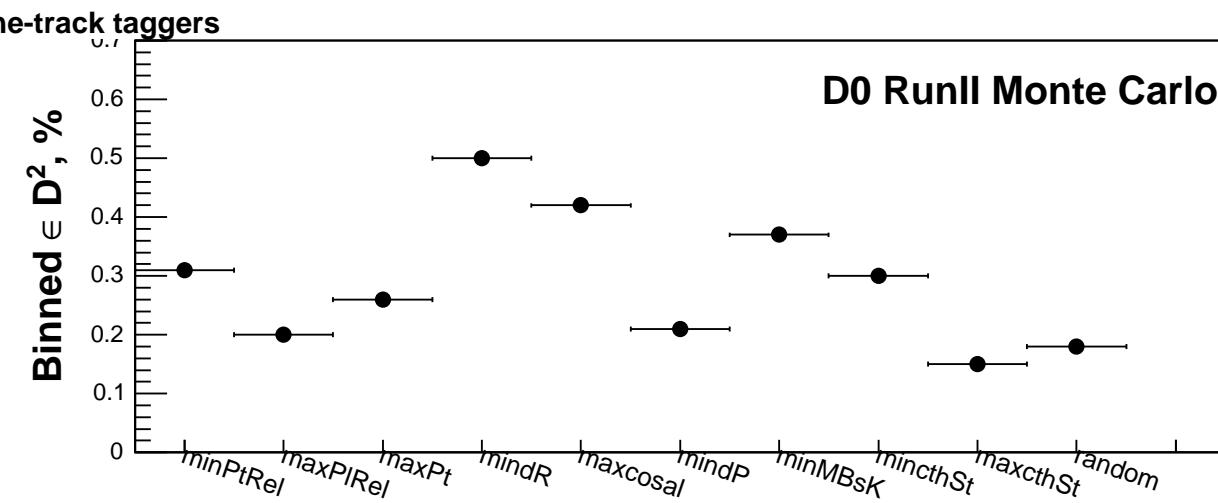


Calibration curves for “Min. ΔR ” tagger for Monte Carlo

- “Binned” ϵD^2 is expected to be higher than direct product of ϵ and D^2 (which I call “unbinned” ϵD^2)
- The difference between them stems from difference between $\langle D^2 \rangle$ and $\langle D \rangle^2$ and may be significant

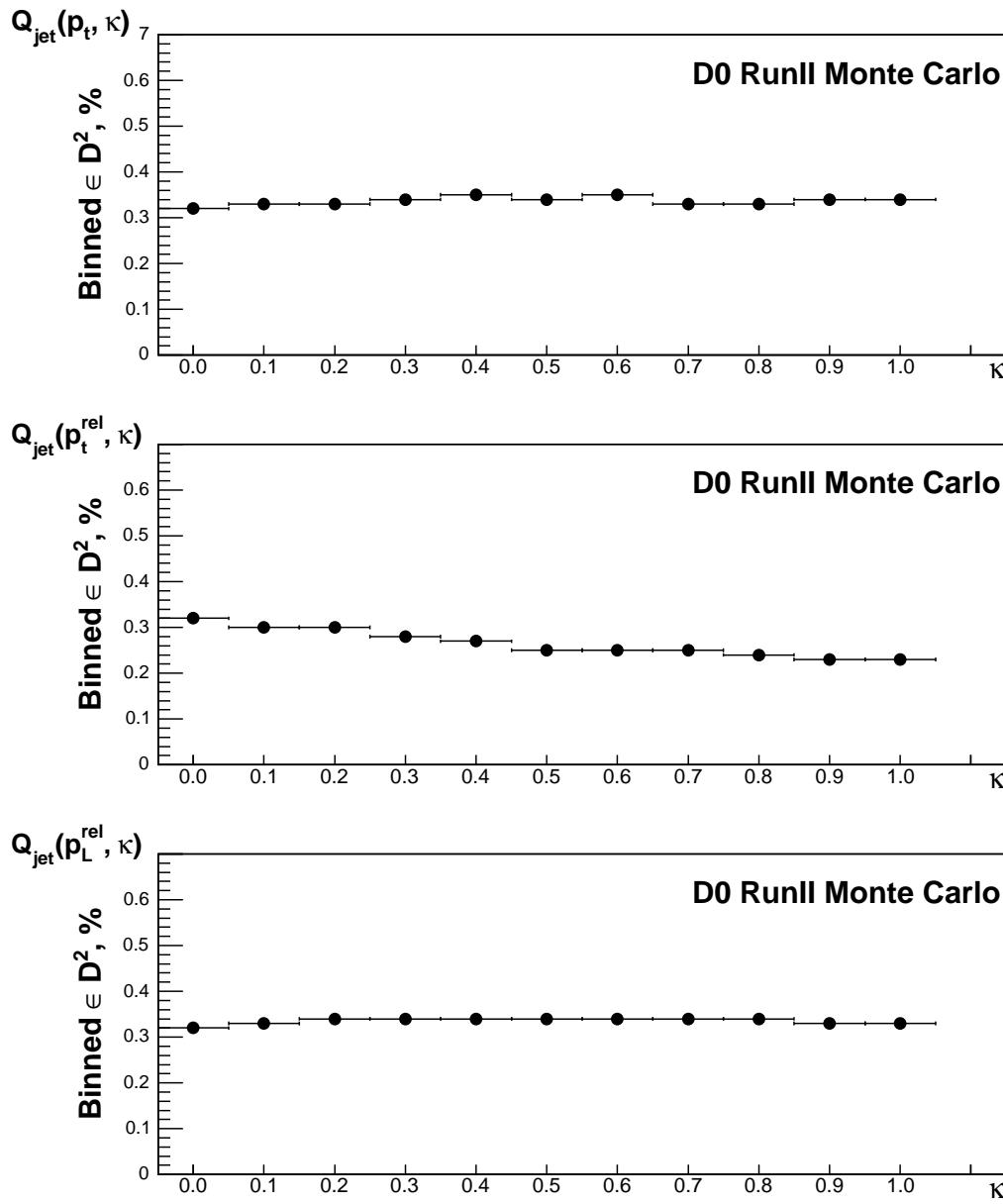
One-track taggers in MC

Tagger	ε , %	D, %	"Unbinned" εD^2 , %	"Binned" εD^2 , %
Min. p_t^{rel}	74.6 ± 0.2	6.2 ± 0.2	0.29 ± 0.02	0.32 ± 0.02
Max. p_L^{rel}	74.6 ± 0.2	4.7 ± 0.2	0.17 ± 0.02	0.23 ± 0.02
Max. p_t	74.6 ± 0.2	5.1 ± 0.2	0.19 ± 0.02	0.26 ± 0.02
Min. ΔR	74.6 ± 0.2	7.0 ± 0.2	0.36 ± 0.02	0.50 ± 0.03
Max. $\cos \alpha$	74.6 ± 0.2	6.9 ± 0.2	0.36 ± 0.02	0.43 ± 0.03
Min. ΔP	74.6 ± 0.2	4.9 ± 0.2	0.18 ± 0.02	0.21 ± 0.02
Min. $m(B_s K)$	74.6 ± 0.2	6.6 ± 0.2	0.33 ± 0.02	0.38 ± 0.02
Min. $\cos \theta^*$	74.6 ± 0.2	6.1 ± 0.2	0.27 ± 0.02	0.31 ± 0.02
Max. $\cos \theta^*$	74.6 ± 0.2	4.0 ± 0.2	0.12 ± 0.01	0.15 ± 0.01
Random	74.6 ± 0.2	4.6 ± 0.2	0.16 ± 0.02	0.18 ± 0.02



“Binned” εD^2 is greater than “unbinned” one

Many-track taggers in MC

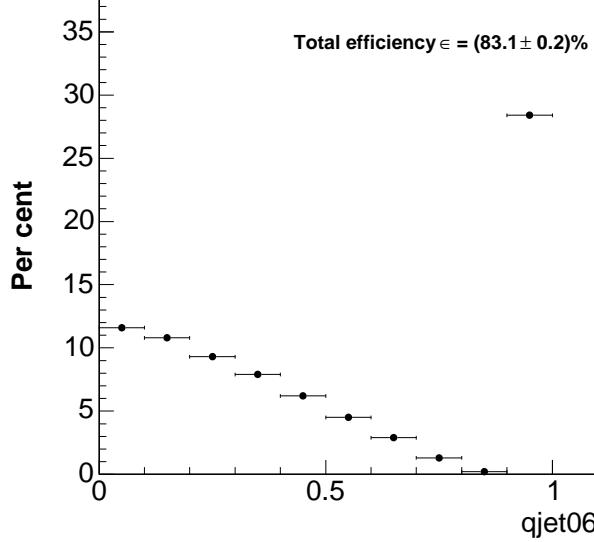


- Graphical comparison of “binned” tagging powers ϵD^2 of many-track taggers weighted with p_t^κ , $(p_t^{rel})^\kappa$, $(p_L^{rel})^\kappa$ in Monte Carlo
- None of them is significantly better than others - choose $Q_{jet}(p_t, \kappa = 0.6)$ following example of OST

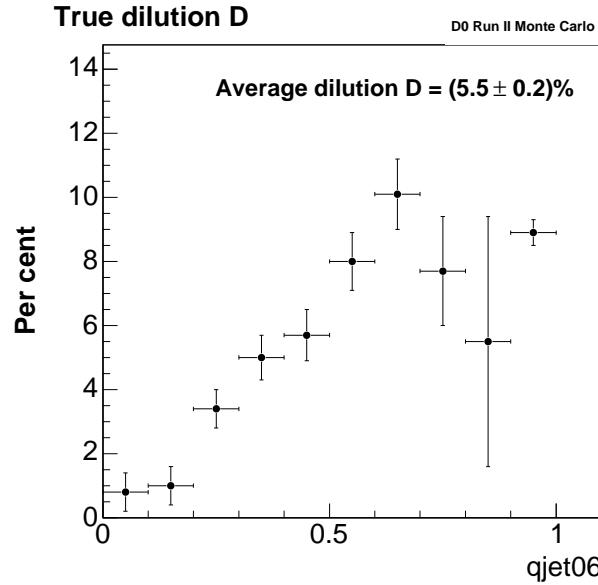


Best many-track tagger: “ $Q_{jet}(p_t, \kappa = 0.6)$ ”

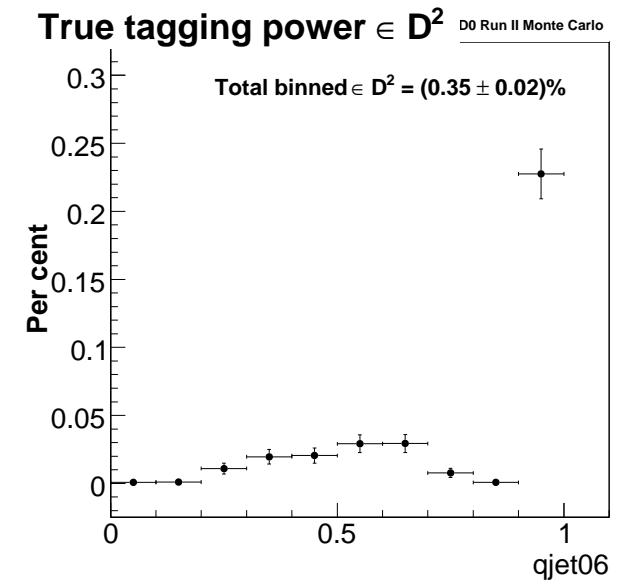
True tagging efficiency \in D0 Run II Monte Carlo



True dilution D



True tagging power $\in D^2$



Calibration curves for “ $Q_{jet}(p_t, \kappa = 0.6)$ ” tagger for Monte Carlo

Tagger	$\epsilon, \%$	D, %	“Unbinned” $\epsilon D^2, \%$	“Binned” $\epsilon D^2, \%$
$Q_{jet}(\kappa = 0.6)$	83.3 ± 0.2	5.5 ± 0.2	0.25 ± 0.02	0.35 ± 0.02

Combination of same-side B -flavor taggers:

Combination algorithm (developed for OST):

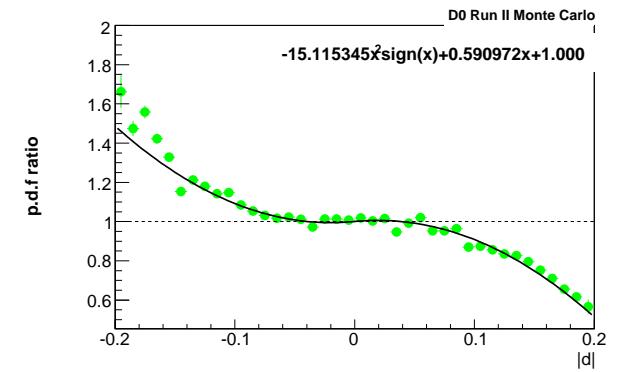
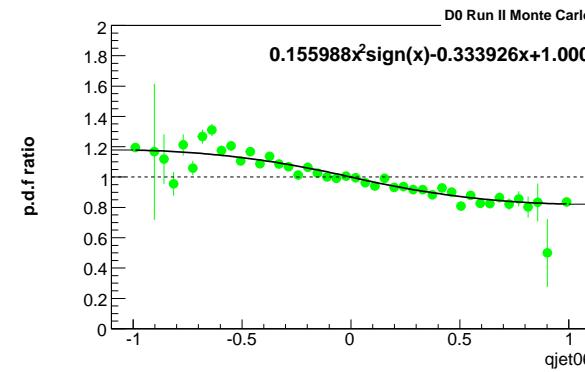
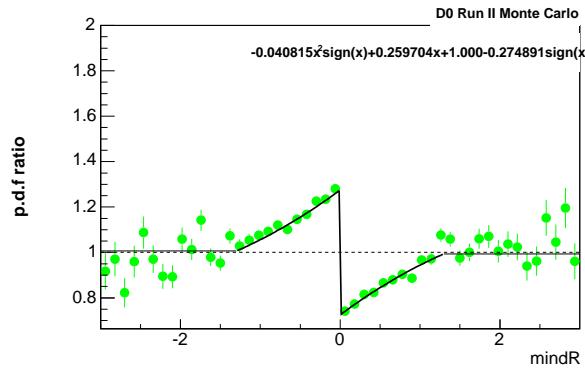
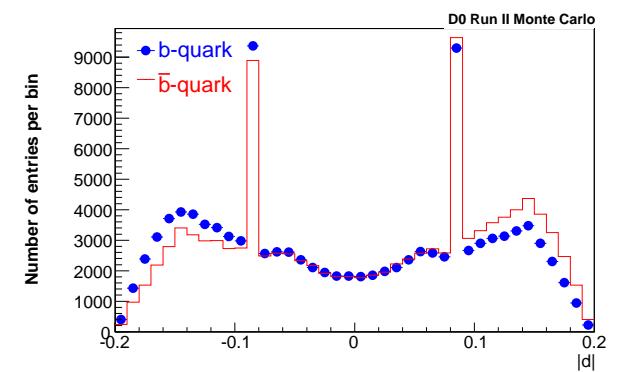
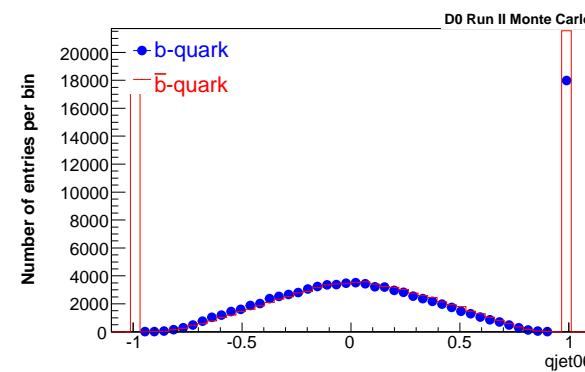
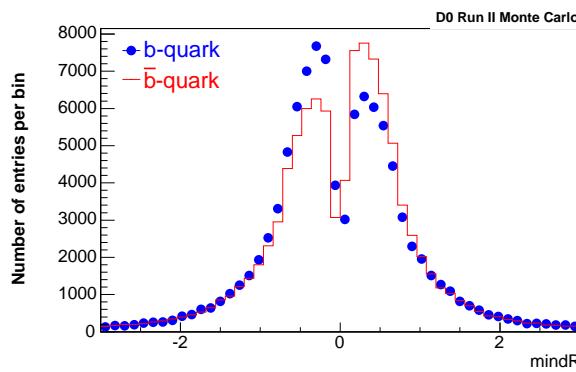
- Find uncorrelated discriminating variables x_i with p.d.f. $f_i^b(x_i)$ and $f_i^{\bar{b}}(x_i)$ being different for b and \bar{b} quarks
- Define tagging variables $y_i = \frac{f_i^b(x_i)}{f_i^{\bar{b}}(x_i)}$; $y_i > 1 - b\text{-quark}$, $y_i < 1 - \bar{b}\text{-quark}$
- Define combined tagging variable $y = \prod y_i$
- Introduce combined tagging variable $d = \frac{1-y}{1+y}$ for each event
- Infer B -flavor from sign of variable d
- **Determine “unbinned” combined tagging power:**
 - ☞ Multiply efficiency by dilution squared
- **Determine “binned” combined tagging power:**
 - ☞ Bin sample in this variable d
 - ☞ Plot dependence of efficiency and dilution vs. d
 - ☞ Obtain “binned” combined ϵD^2 as a sum of ϵD^2 's in each bin

P.d.f.'s for “Min. ΔR ” and “ $Q_{jet}(p_t, \kappa = 0.6)$ ” taggers:

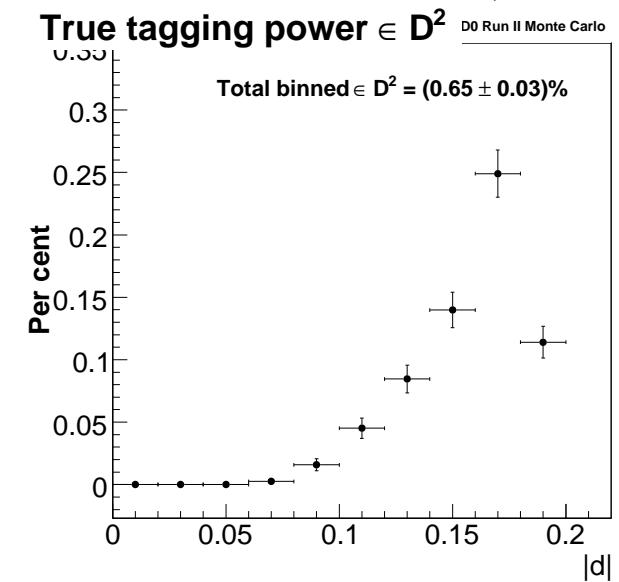
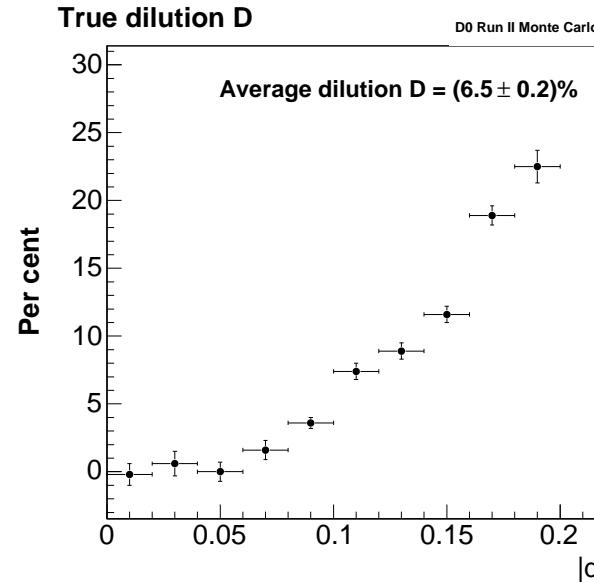
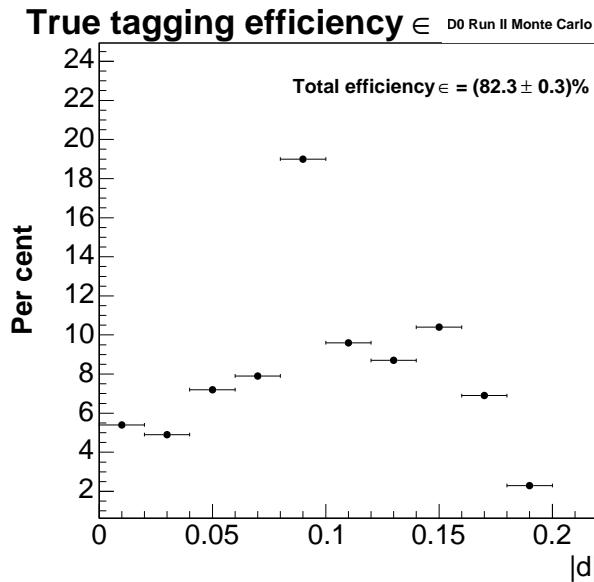
“Min. ΔR ”

“ $Q_{jet}(p_t, \kappa = 0.6)$ ”

“Comb. SST”



Combined SST



Calibration curves for combined same-side tagger in Monte Carlo

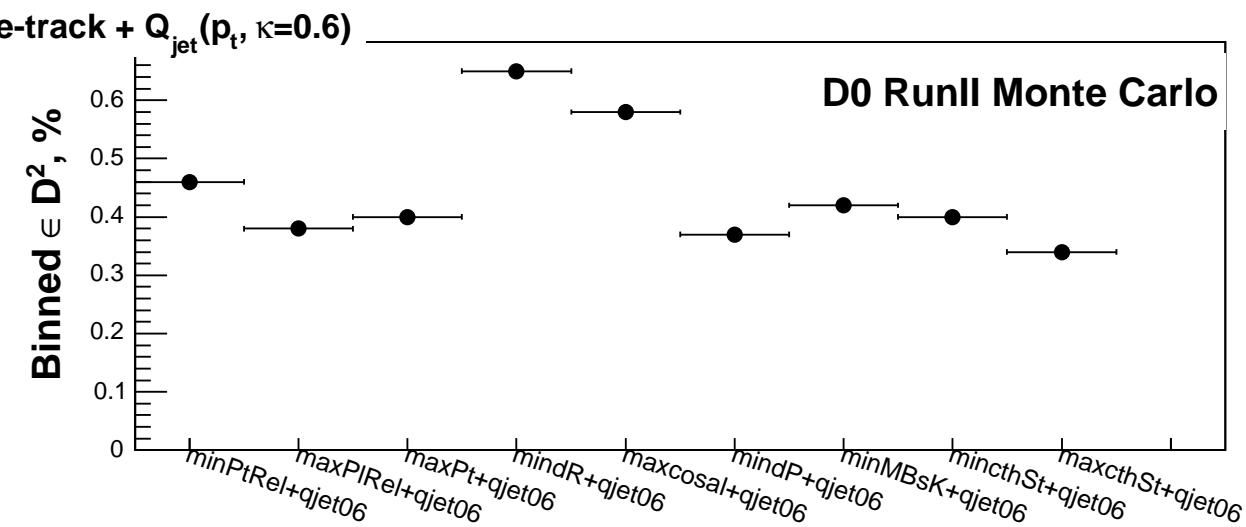
Tagger	ϵ , %	D, %	"Unbinned" ϵD^2 , %	"Binned" ϵD^2 , %
"Min. ΔR "	74.6 ± 0.2	7.0 ± 0.2	0.36 ± 0.02	0.50 ± 0.03
" $Q_{jet}(\kappa = 0.6)$ "	83.3 ± 0.2	5.5 ± 0.2	0.25 ± 0.02	0.35 ± 0.02
"Min. ΔR " + " $Q_{jet}(\kappa = 0.6)$ "	83.3 ± 0.2	6.4 ± 0.2	0.34 ± 0.02	0.65 ± 0.03

We see increase in ϵD^2 due to tagger combination

Other one-track SST's

We check if “Min. ΔR ” + “ $Q_{jet}(\kappa = 0.6)$ ” is really the best combination:

Tagger	$\varepsilon, \%$	D, %	“Unbinned” $\varepsilon D^2, \%$	“Binned” $\varepsilon D^2, \%$
Min. $p_t^{rel} + Q_{jet}(p_t, \kappa = 0.6)$	83.3 ± 0.2	5.9 ± 0.2	0.29 ± 0.02	0.46 ± 0.03
Max. $p_L^{rel} + Q_{jet}(p_t, \kappa = 0.6)$	83.3 ± 0.2	4.9 ± 0.2	0.20 ± 0.02	0.38 ± 0.03
Max. $p_t + Q_{jet}(p_t, \kappa = 0.6)$	83.3 ± 0.2	5.0 ± 0.2	0.20 ± 0.02	0.40 ± 0.03
Min. $\Delta R + Q_{jet}(p_t, \kappa = 0.6)$	83.3 ± 0.2	6.4 ± 0.2	0.34 ± 0.02	0.65 ± 0.03
Max. $\cos \alpha + Q_{jet}(p_t, \kappa = 0.6)$	83.3 ± 0.2	6.5 ± 0.2	0.36 ± 0.02	0.58 ± 0.03
Min. $\Delta P + Q_{jet}(p_t, \kappa = 0.6)$	83.3 ± 0.2	4.9 ± 0.2	0.20 ± 0.02	0.37 ± 0.02
Min. $m(B_s K) + Q_{jet}(p_t, \kappa = 0.6)$	83.3 ± 0.2	6.4 ± 0.2	0.34 ± 0.02	0.42 ± 0.03
Min. $\cos \theta^* + Q_{jet}(p_t, \kappa = 0.6)$	83.3 ± 0.2	5.8 ± 0.2	0.28 ± 0.02	0.40 ± 0.02
Max. $\cos \theta^* + Q_{jet}(p_t, \kappa = 0.6)$	83.3 ± 0.2	5.0 ± 0.2	0.21 ± 0.02	0.34 ± 0.02



No problems so far – SST-only part ready to be published

Opposite-side tagger

- Developed previously (BANA package)
- P.d.f. taken from data
- Mis-represented by most of existing MC samples (factor of 2 lower dilution)
- Best representation: “unbiased” MC sample (similar dilution but factor of 2 lower efficiency)

Tagger	ϵ , %	D, %	“Unbinned” ϵD^2 , %	“Binned” ϵD^2 , %
“Comb. OST” ($ d > 0.3$, PRD)	11.14 ± 0.15	44.3 ± 2.2	2.19 ± 0.22	–
“Comb. OST” ($ d > 0.3$, our Monte Carlo)	20.7 ± 0.1	40.0 ± 0.4	3.31 ± 0.07	–
“Comb. OST” (no cut on $ d $, PRD)	19.95 ± 0.21	–	–	2.48 ± 0.21
“Comb. OST” (no cut on $ d $, our Monte Carlo)	33.10 ± 0.13	–	–	–

- Not clear which dilution to use when combining with SST
- Not clear how to compare ϵD^2 's
- Not clear if we can use this MC for simulating OST at all

Nevertheless let's try to use this MC to see if SST and OST are correlated with each other

SST-OST correlations

Tagger	D_{SST} with OST	D_{SST} without OST	D_{OST} with SST	D_{OST} without SST
"Comb. SST" + "Comb. OST"	7.6 ± 0.5	6.1 ± 0.2	39.4 ± 0.4	42.9 ± 0.9
"Min. ΔR " + "Comb. OST"	7.8 ± 0.5	6.7 ± 0.2	38.9 ± 0.5	43.0 ± 0.7
" $Q_{jet}(p_t, \kappa = 0.6)$ " + "Comb. OST"	7.6 ± 0.5	5.0 ± 0.2	39.4 ± 0.4	42.9 ± 0.9
"Min. p_t^{rel} " + "Comb. OST"	6.7 ± 0.5	6.1 ± 0.2	38.9 ± 0.5	43.0 ± 0.7
"Min. ΔR " + " μ OST"	8.1 ± 0.6	6.8 ± 0.2	35.6 ± 0.6	39.9 ± 1.0
" $Q_{jet}(p_t, \kappa = 0.6)$ " + " μ OST"	7.6 ± 0.6	5.2 ± 0.2	36.2 ± 0.6	38.9 ± 1.2
"Min. p_t^{rel} " + " μ OST"	6.3 ± 0.6	6.2 ± 0.2	35.6 ± 0.6	39.9 ± 1.0

- We observe some correlation
- Presence of OST increases SST dilution
 - Effect almost vanishes for "Min. p_t^{rel} " SST and muon OST
- Presence of SST decreases OST dilution (totally unclear)

There are two reasons for correlations:

- Using the same tracks (being checked, found nothing so far)
- p_t correlations between tracks in OST-cone and SST-cone (© S. Burdin)

Despite all these correlations let's try to combine SST and OST

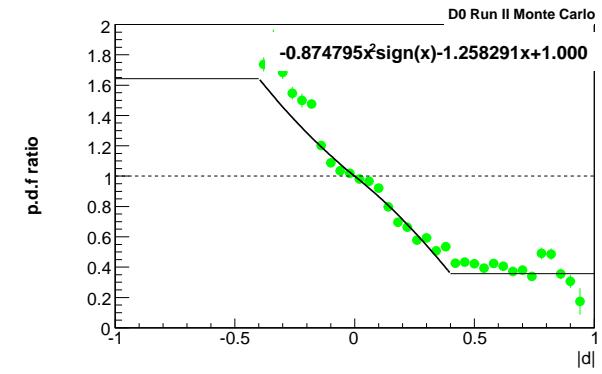
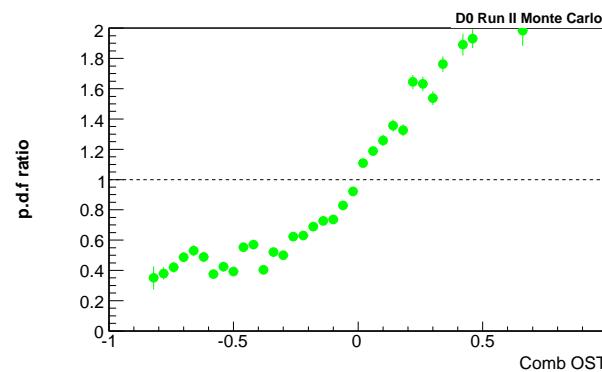
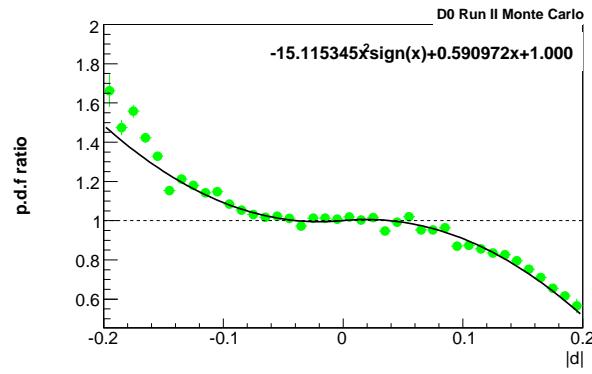
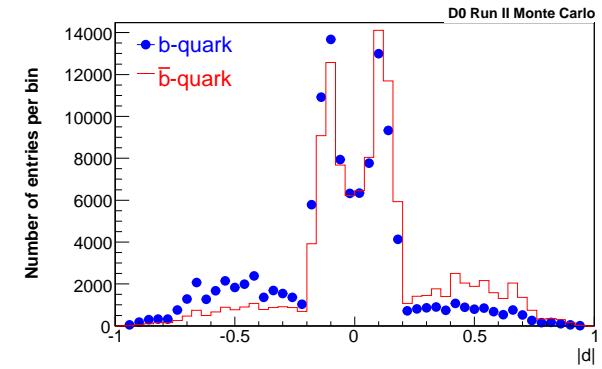
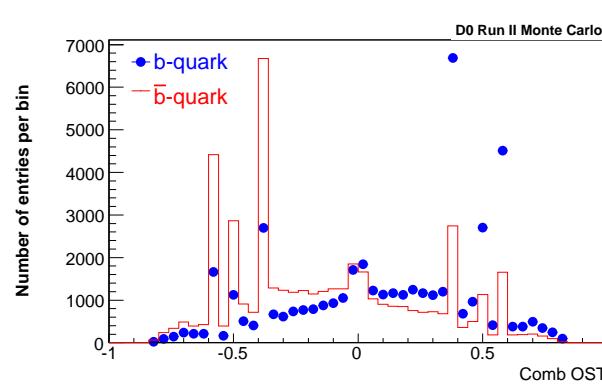
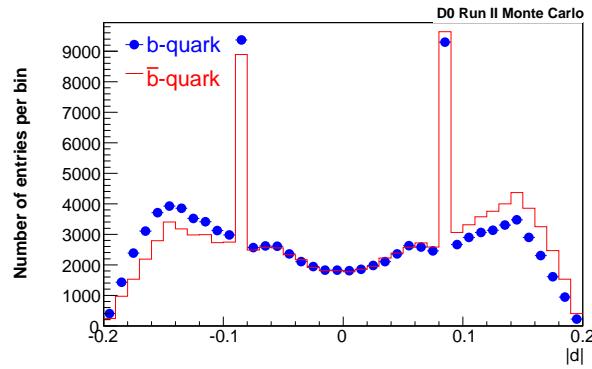
Combination of SST + OST:

There are different algorithms, we need to choose the best one:

- **Monte-Carlo-pdf-based** (same as for combining SSTs):
 - Combination algorithm is the same as for combination of SSTs:
 - Multiply p.d.f.s for SST and OST
 - Introduce combined tagging variable $d = \frac{1 - \prod \frac{f^b(x)}{f^{\bar{b}}(x)}}{1 + \prod \frac{f^b(x)}{f^{\bar{b}}(x)}}$ for each event
 - Infer B -flavor from sign of this variable d
- **Data-calibration-curve-based:**
 - Uses double-tagged events to obtain calibration curve from data only

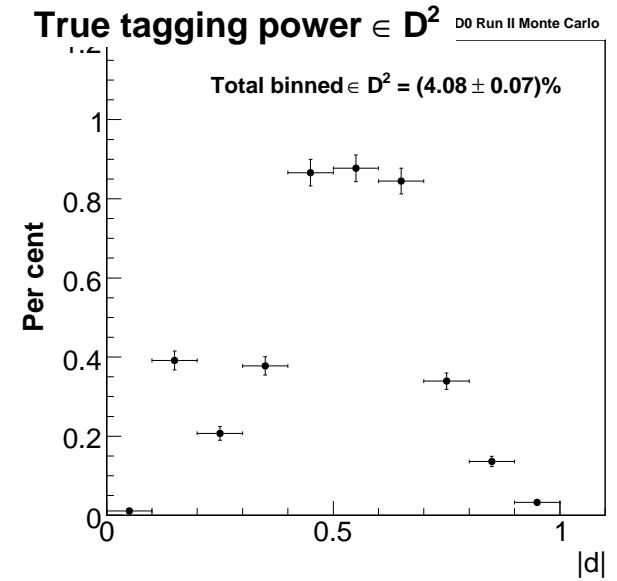
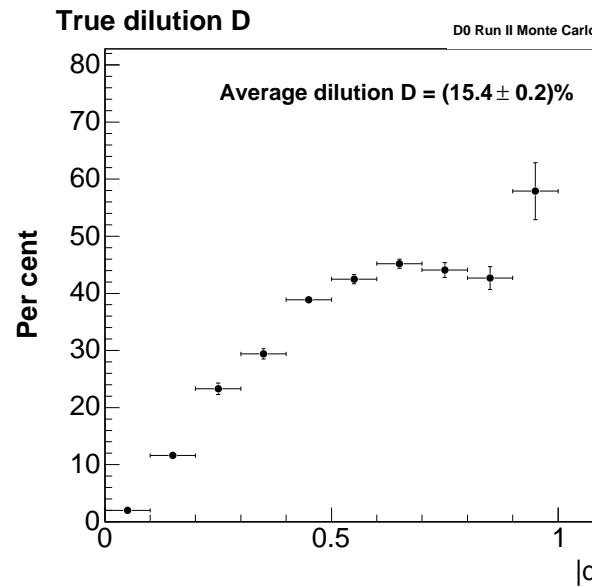
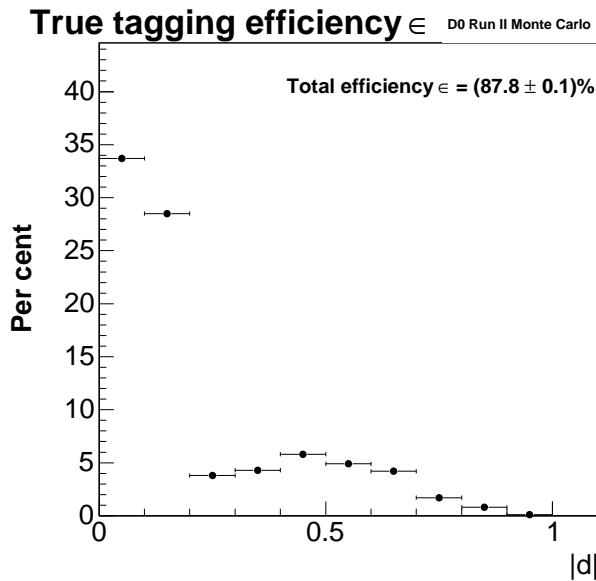


Monte-Carlo-p.d.f.-based SST + OST: SST OST SST+OST





Monte-Carlo-p.d.f.-based SST + OST:



Calibration curves for combined SST + OST in Monte Carlo.

Tagger	ϵ , %	D, %	"Unbinned" ϵD^2 , %	"Binned" ϵD^2 , %
"Comb. SST" only	83.3 ± 0.2	6.4 ± 0.2	0.34 ± 0.02	0.65 ± 0.03
"Comb. OST" (PRD)	11.14 ± 0.15	44.3 ± 2.2	2.19 ± 0.22	2.48 ± 0.21
"Comb. OST" (in our Monte Carlo)	20.7 ± 0.1	40.0 ± 0.4	3.31 ± 0.07	-
"Comb. SST" + "Comb. OST"	88.4 ± 0.2	15.2 ± 0.2	2.05 ± 0.05	4.08 ± 0.07

Very low "unbinned" ϵD^2 for "Comb. SST" + "Comb. OST". Anticorrelation?

Double-tag method

- The p.d.f.-based method suffers from relying on Monte Carlo
- Double-tag method uses data only:
 - Uses events tagged with SST and OST simultaneously
 - Let N_{12} such events be tagged identically, \bar{N}_{12} tagged oppositely
 - Then $D_{SST} \cdot D_{OST} = \frac{N_{12} - \bar{N}_{12}}{N_{12} + \bar{N}_{12}}$ (provided that taggers uncorrelated)
 - Knowing D_{OST} from PRD we can measure D_{SST}
- Double-tag method inherently has larger uncertainty
- We apply double-tag method to MC (to check if it works) and data
 - Due to SST-OST correlations measured dilution in MC is factor of 2 higher than true dilution

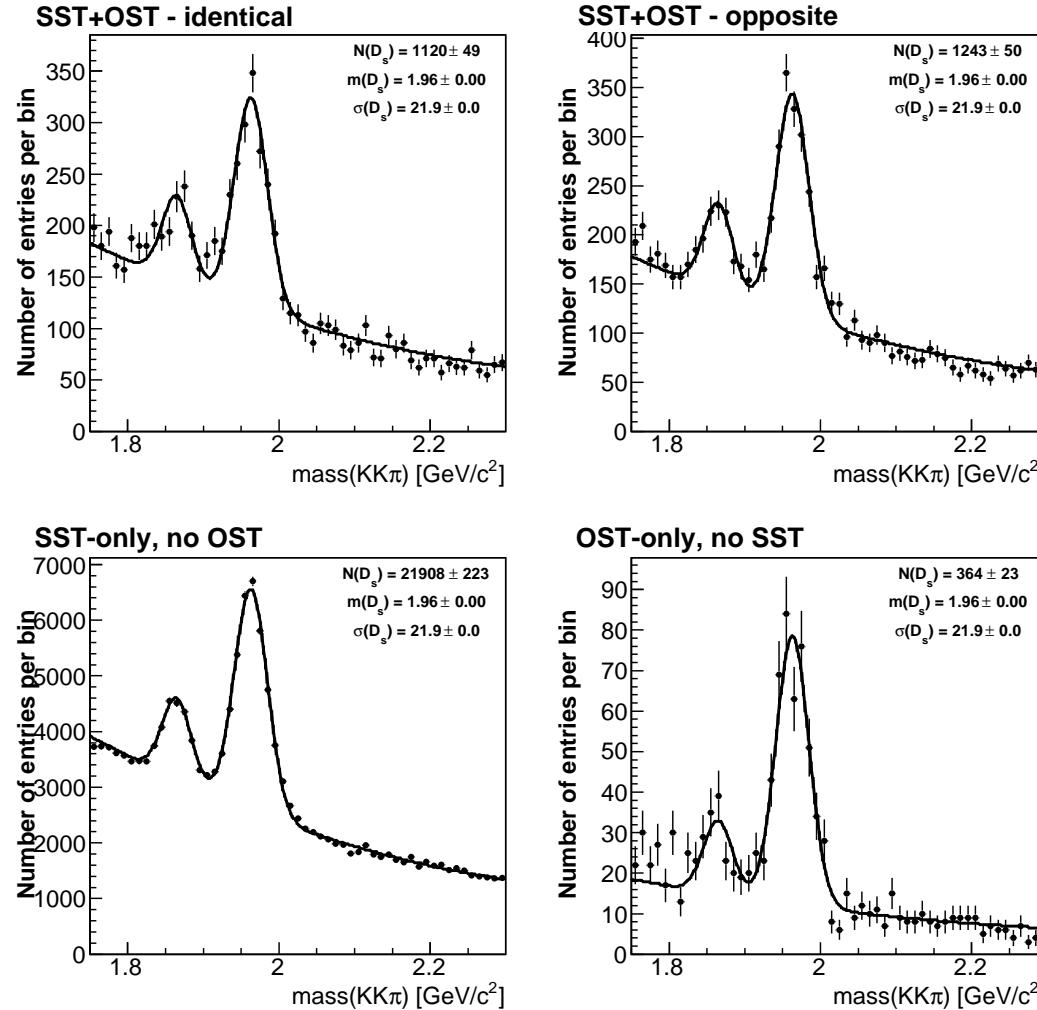


Double-tag method in Monte Carlo:

Tagger	N_{12}	\bar{N}_{12}	D_{SST}^{meas}	D_{SST}^{true}	$\varepsilon D^2_{SST+OST}, \%$ ("unbinned")
(Min. p_t^{rel} + $Q_{jet}(0.6)$)+OST	24470 ± 156	22469 ± 150	9.62 ± 1.15	5.9 ± 0.2	4.79 ± 0.32
(Max. p_L^{rel} + $Q_{jet}(0.6)$)+OST	24576 ± 157	22363 ± 150	10.64 ± 1.17	4.9 ± 0.2	4.95 ± 0.31
(Max. p_t + $Q_{jet}(0.6)$)+OST	24527 ± 157	22412 ± 150	10.17 ± 1.16	5.0 ± 0.2	4.87 ± 0.32
(Min. $ \Delta \vec{P} $ + $Q_{jet}(0.6)$)+OST	24579 ± 157	22360 ± 150	10.67 ± 1.17	6.4 ± 0.2	4.95 ± 0.31
(Min. ΔR + $Q_{jet}(0.6)$)+OST	24557 ± 157	22382 ± 150	10.46 ± 1.16	4.9 ± 0.2	4.92 ± 0.31
(Max. $\cos \alpha$ + $Q_{jet}(0.6)$)+OST	24763 ± 157	22176 ± 149	12.44 ± 1.21	6.4 ± 0.2	5.27 ± 0.31
(Min. $\cos \theta^*$ + $Q_{jet}(0.6)$)+OST	24573 ± 157	22366 ± 150	10.61 ± 1.17	5.8 ± 0.2	4.94 ± 0.31
(Max. $\cos \theta^*$ + $Q_{jet}(0.6)$)+OST	24470 ± 156	22469 ± 150	9.62 ± 1.15	5.9 ± 0.2	4.79 ± 0.32
(Min. $m(B_s K)$ + $Q_{jet}(0.6)$)+OST	24763 ± 157	22176 ± 149	12.44 ± 1.21	6.4 ± 0.2	5.27 ± 0.31

- Measured dilutions are twice as high as true dilutions

Example: Data fit for double-tag method for “Min. ΔR ” tagger





Double-tag method in data:

Tagger	N_{12}	\bar{N}_{12}	D_{SST}^{meas}	$\varepsilon D^2_{SST+OST}, \%$ ("unbinned")
(Min. $p_t^{rel} + Q_{jet}(0.6)$)+OST	1246 ± 50	1127 ± 49	11.34 ± 6.70	3.02 ± 1.28
(Max. $p_L^{rel} + Q_{jet}(0.6)$)+OST	1275 ± 51	1100 ± 49	16.63 ± 6.73	4.27 ± 1.88
(Max. $p_t + Q_{jet}(0.6)$)+OST	1271 ± 51	1098 ± 49	16.51 ± 6.75	4.23 ± 1.87
(Min. $\Delta R + Q_{jet}(0.6)$)+OST	1120 ± 49	1243 ± 50	11.80 ± 6.74	3.03 ± 1.30
(Min. $\Delta P + Q_{jet}(0.6)$)+OST	1288 ± 51	1088 ± 48	19.01 ± 6.68	4.99 ± 2.13
(Min. $m(B_s K) + Q_{jet}(0.6)$)+OST	1258 ± 51	1118 ± 48	13.35 ± 6.65	3.44 ± 1.49
(Min. $\cos \theta^* + Q_{jet}(0.6)$)+OST	1298 ± 51	1077 ± 48	21.02 ± 6.71	5.66 ± 2.36
(Max. $\cos \theta^* + Q_{jet}(0.6)$)+OST	1223 ± 50	1155 ± 49	6.37 ± 6.68	2.28 ± 0.73
(Max. $\cos \alpha + Q_{jet}(0.6)$)+OST	1266 ± 50	1103 ± 49	15.49 ± 6.74	3.95 ± 1.75

Measured dilutions in data are reasonably close to measured dilutions in Monte Carlo, but very far from true dilutions in Monte Carlo



Conclusion

- SST-only part of the analysis is ready to be published (at NIM)
- Combinations SST + OST still needs to be fixed
- Questionable OST Monte Carlo
- We observe correlations between SST and OST
- P.d.f.-based method: too low “unbinned” ϵD^2 for SST + OST
- Double-tag method: Measured dilutions in MC are twice as large as true dilutions due to above mentioned correlations